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Increasing residential solar installations in California: Have local permitting processes historically driven differences between cities?

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ABSTRACT

Local governments are agile policy makers expected to make significant contributions to climate change mitigation through local legislation. One mitigation mechanism available to local governments is to make it easier for households to install solar photovoltaic (PV) panels that generate emission-free electricity. Streamlining PV permitting policies is currently being promoted in states such as California as a way to boost rates of residential solar installation. Fixed effects modelling is used to examine whether streamlining permitting for PV increased rates of PV installations in California prior to 2013. To fill a gap in longitudinal data on implementation dates of local policies to support PV, a combination of surveys, partial databases, and publicly available city-level information is utilized to build a complete picture of changes in relevant policies from 2005 to 2013. Modelling results are unable to reject the null hypothesis that the implementation of streamlined permitting has no effect on residential PV installation rates. This highlights the limitations of what can be assessed given the current sparsity of data on city-level policy changes even employing significant original data collection and compilation.

1. Introduction

Urban areas account for up to 76% of CO_2 emissions globally (Seto et al., 2014). This, combined with the comparatively fast pace at which city governments are able to enact policies (Feiock et al., 2013), positions cities as a potentially critical arena for measures to reduce greenhouse gas (GHG) emissions. Over the past several decades, city governments have become increasingly involved in efforts to reduce GHG emissions and mitigate climate change (Bulkeley, 2010), and have continued to gain prominence since international and national-level agreements and policies often stall during negotiations (Betsill and Rabe, 2009; Bulkeley and Betsill, 2013). Encouraging distributed renewable generation, particularly solar photovoltaic (PV) panels, is one of the ways that cities can reduce GHG emissions associated with their jurisdiction. Determining which city government policies have a measurable impact on residential solar PV installations could aid city governments in allocating resources for climate change mitigation, to the extent that local jurisdictions are able to set renewable energy goals independent of regional and national actors.

One mechanism by which local governments are expected to be able to increase PV installations is by removing relevant barriers, whether these are financial, regulatory, or time barriers. California is currently attempting to remove some of these barriers with AB 2188, a measure that mandates all local jurisdictions in California adopt an ordinance creating an expedited, streamlined permitting process for small rooftop solar PV systems by September 2015 (Kaatz and Anders, 2015). There is an expectation that reducing barriers to installing residential PV will increase installation rates; permitting application procedures, review times, and fees have been identified as significant barriers to installing residential solar (Pitt, 2008), and several recent papers indicate that local governments could reduce residential solar PV costs and installation times by streamlining permitting processes (Burkhardt et al., 2015; Dong and Wiser, 2013; Seel et al., 2014). However, there was no analysis prior to rolling out AB 2188 that confirmed whether streamlining solar permitting would effectively increase the rate of residential PV installation, despite several cities in California having chosen to streamline permitting processes in earlier years.

This paper examines whether California cities that streamlined permitting in years prior to the implementation of AB 2188 observed higher rates of PV installation, using data up to the year 2013 before AB 2188 was in effect.[1] Previous studies examining impacts of residential PV permitting on installation rates have examined data from only one

Abbreviations: CEC, California Energy Commission; CPUC, California Public Utilities Commission; ICLEI, "Local Governments for Sustainability" network; IREC, Interstate Renewable Energy Council; IOU, Investor Owned Utility; POU, Publicly Owned Utility; TPO, Third Party Ownership

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[1] 2013 also marks the year when record keeping of solar installation data transferred between different state agencies, and so there is discontinuous data between 2013 and 2014 that restricts the end-year usable for analysis (Lawrence Berkeley National Lab, 2016b).

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Table 1
Descriptive statistics for main sample (57 cities).

Variables	Units	Mean	SD	Min	Max
Watts of PV installed annually	Watts/capita (i.e., W/capita or kW/1000 people)	4.20	7.04	0.017	64.39
Number of PV systems installed annually	PV systems/1000 people	0.90	1.41	0.01	11.72
Streamlined permitting	1 if permitting was streamlined,0 otherwise	0.11	0.31	0	1
Permitting fees < $400[a]	1 if permitting fee under $400,0 otherwise	0.28	0.48	0	1
PACE[a]	1 if PACE program in place,0 otherwise	0.24	0.42	0	1
Electricity price[b]	$/kWh	0.15	0.02	0.08	0.18
Financial incentives[b]	$/kW installed	1.84	1.06	0.00	4.50
Median age[b]	Years	34.10	3.40	25.70	43.00
Share of registered democrats	Percent	43.21	8.12	28.00	58.00
Share of households with income > $100,000	Percent	26.76	10.19	5.30	54.10
Share of households with income $100,000 to $50,000	Percent	31.27	4.08	21.50	45.30
Share with bachelor's degree or higher	Percent	30.47	13.90	7.30	69.9

[a] Values for sub-sample (23 cities).
[b] prior to non-linear transformations.

or two years of city permitting practices (Hsu, 2018); the current paper contributes to the literature by using fixed effects analysis to examine, for a sample of California cities through the years 2005–2013, the impacts on existing trends in PV installation when cities increase the availability of online information for permitting and achieve average turnaround times for residential solar permit issuance of three days or less. No data set previously existed recording changes in cities' solar permitting practices over several years, and the current paper further contributes to the literature by developing this data set for cities in California over nine years.

2. Predictors of residential PV adoption

Permitting can add unnecessary complexity for both households and installers, and soft costs can make up 30–40% of the total cost for a PV system (Treadwell et al., 2012). High fees, long permitting times, and lack of widely accessible permitting information may all contribute small but potentially significant barriers to the already expensive and lengthy process of installing residential solar PV (IREC, 2013). Variations in permitting procedures between jurisdictions are associated with average installation cost differences of $0.18/W installed for residential PV systems across the US between the best and worst cities, and streamlining permitting processes could reduce PV costs in California specifically by $0.27-$0.77/W (Burkhardt et al., 2015; Dong and Wiser, 2013). The time that it takes to issue permits can vary from a few hours to over a month, and long wait times introduce additional costs and frustrations to bringing PV systems online (Dong and Wiser, 2013; IREC, 2013).

Several recent papers have examined individual level and zip-code level predictors of residential PV adoption (Davidson et al., 2014; Kwan, 2012; Robinson and Rai, 2015). One prior study that examined streamlined permitting impacts in the context of comparing city versus state policies found no impact of permitting policies (Li and Yi, 2014), but did not take into consideration factors such as how long streamlined permitting policies had been in place, and did not restrict the sample to residentially-sized PV systems. Another prior study found that the presence of streamlined permitting processes in a city correlates with greater installed PV capacity, but only used data on permitting processes for the years 2010 and 2011 and so was not able to confirm that streamlining permitting policies causes a change in rate of residential PV installations (Hsu, 2018).

PV adoption is predicted by demographics at the individual level and zip-code level, with higher income groups, older residents, and more educated residents being more likely to adopt PV (Davidson et al., 2014; Kwan, 2012). At the individual and zip-code level PV adoption is positively predicted by higher home values, higher cost of electricity, lower housing density, and presence of financial incentives (Davidson et al., 2014; Kwan, 2012). Availability of Property-Assessed Clean

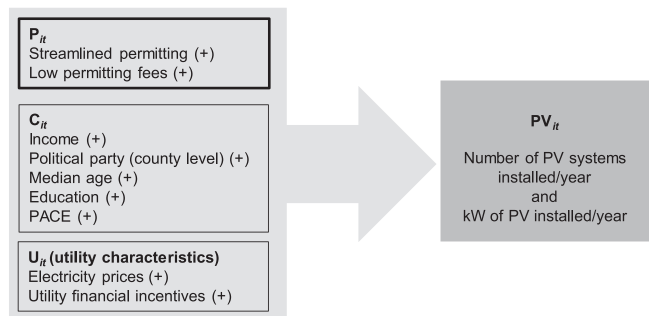

Fig. 1. Factors expected to drive city-level differences in residential PV installation rates. Signs indicate expected direction of effect on PV installation rates.

Energy (PACE) financing has also been found to increase installation rates of residential solar PV (Kirkpatrick and Bennear, 2014).

3. Method

This analysis focuses specifically on PV installations in cities within the state of California. Multi-year panel data on city policy status was not readily available, and was compiled from multiple sources as described in Section 3.2. Since US Census American Community Survey (ACS) 1-year data was used for consistency, only cities with populations over 65,000 in all years 2005–2013 had full demographic data available. The initial set of cities for which PV installation rates and policy data were sought contained 114 localities with populations over 65,000 for years 2005–2013, but only 98 of these had PV installation records for all years. Of these 98, only 57 had definitive permitting records and only 23 had definitive information regarding permitting fees specifically for residential solar PV for all years of interest (following procedures described in Section 3.2). Thus, fully balanced panel data including streamlined permitting indicators were available for 57 cities, and permitting fees and PACE indicators were examined using a fully-balanced sub-sample of 23 cities. Table 1 provides descriptive statistics for the main sample of 57 cities.

3.1. Empirical approach

Cities that chose to streamline residential solar permitting procedures may be inherently different from those that did not, and these differences may drive higher solar installation rates even prior to streamlining permitting. This poses a problem of selection bias, which can be partially addressed by using fixed effects analysis to control for time- and city-invariant differences (see Eq. (1)). Fixed effects modelling assumes that there are no time- and city-specific unobserved factors

Table 2
Permitting timing, availability, and fee information for the treated cities included in the final sample. Cities with incomplete fee information were excluded from the sub-sample analysis, as were cities that waived permitting fees for some years then reintroduced fees.

City	Permitting three days or less	Permitting information online	Met both permitting criteria	Major permitting fee changes where known
Antioch	2013	2013	2013	From $745 in 2007 to $243 in 2008
Berkeley	2011	2009	2011	Waived fees 2008 only
Fremont	2009	2009	2009	From $850 in 2006 to $237 in 2007
Lancaster	2010	2010	2010	$61 flat fee introduced 2010
Long Beach	2009	2009	2009	From $599 in 2009 to $233 in 2010
Sacramento	2009	2009	2009	Waived fees 2007–2009 only
San Diego	2012	2006	2012	Unknown
San Francisco	2007	2008	2008	$85-$170 all years
Santa Barbara	2006[a]	2007	2007	No changes known ($430)
Santa Clara	2009	2009	2009	Unknown
Vista	2009[a]	2011	2011	Unknown

[a] Or earlier.

correlated with the treatment, i.e., no "contemporaneous shocks." This is a more plausible assumption to meet than the assumption necessary for cross-sectional analysis that there is no unobserved heterogeneity between cities. The model is represented by the Eq. (1), which corresponds to the predictors outlined in Fig. 1:

$$PV_{it} = \alpha_i + \gamma_t + \beta P_{it} + \delta C_{it} + \theta U_{it} + \varepsilon_{it} \quad (1)$$

Where PV_{it} represents the number of new systems installed in a given year; α_i represents a city-specific intercept; γ_t represents year fixed effects; P_{it} represents permitting practices of different cities; C_{it} represents other city-level differences expected to impact PV development, including income and median age; and U_{it} represents utility characteristics including average electricity price in each year and level of financial rebate for solar offered each year. The coefficient β gives the average effect of permitting practices. Errors for the fixed effects regression were clustered at the city level, to avoid overstating of effects due to serial correlation in the time-series data.

To determine whether cities with complete data available regarding permitting speed and process had different underlying PV installation rates compared to cities that had no such data available, a fixed effects regression was run estimating the impact of a missing permit data dummy and year dummies on installed PV capacity. No significant impact was found for missing versus present permitting data on installation rates.

3.2. Permitting data: Processing

3.2.1. Streamlined permitting

Data describing variation in city permitting practices over time is sparse, particularly for years before 2011, so all indicators used for streamlined permitting and permitting fees were collected individually for each city where available. Exploration during early phases revealed that staff who were involved in streamlining permitting often did not remain at the same city government post several years later, precluding structured interviews. The following sections detail how streamlined permitting was defined, and how the data was collected and coded. This streamlined permitting indicator, constructed specifically for the current analysis, covers more years than any previous measure for differences in city permitting practices. Table 2 shows the dates for cities included as treated units; control units were those cities confirmed to have not met both permitting criteria prior to 2013.

3.2.1.1. Defining streamlined permitting. IREC outlines several areas that are considered "best practices" for permitting and as such are expected to predict PV adoption. These are: (1) post requirements online, (2) implement an expedited permit process, (3) enable online permit processing, (4) ensure a fast turnaround time, (5) collect reasonable permitting fees, (6) do not require community-specific licenses, (7) offer a narrow inspection appointment window, (8) eliminate excessive inspections, and (9) train permitting staff in solar (IREC, 2013).

Of these, (1) and (4) are used to construct the streamlined permitting indicator, and (5) is considered separately. This yields a streamlined permitting indicator that requires cities to meet two criteria that are consistent across the guidelines from IREC and California's recent AB 2188, (1) that cities should make checklists for photovoltaic permitting requirements available online and (2) that cities should aim for turnaround times of 3 days or less. Unless a city could be assigned a "1" or "0" for both "Requirements Posted Online" and "Rapid Turnaround Time," it was coded as missing.

3.2.1.2. Original data collection for streamlined permitting indicator. The permitting indicator was seeded with data from Project Permit for the year 2013, then fully populated with data scraped from internet archives.[2] Project Permit, a crowd-sourced map of city permitting practices across the US that is continuously updated, has been used in previous research examining local permitting practices (Burkhardt et al., 2015).

The "Requirements Posted Online" criterion determines the earliest year that city permitting qualified as "streamlined," while ensuring that coding relies on a written record of city permitting practices. A city was only coded "0" for "Requirements posted online" if an archived page of the city's building department was found in any given year that included no links, and made no reference, to any form of solar PV checklist or application procedure. If an archived page was found meeting the prior criteria, then the city was coded "1" for "Requirements posted online." Otherwise, this variable was coded as missing.

"Rapid Turnaround Time" indicates whether cities were generally minimizing delays and associated costs for solar installers and thus homeowners. "Rapid Turnaround Time" was coded as "1" if cities turned around permits in 3 days or less, and "0" if they took longer, reflecting the threshold stated both in AB 2188 and IREC recommendations (IREC, 2013; Kaatz and Anders, 2015). If no information on turnaround time could be found, the city was coded as missing. A more lenient specification whereby "fast turnaround" was 10 days or less was also tested in fixed effects models, and no differences were found regarding which predictors were significant.

[2] https://archive.org/ was used to find archived web pages for each city's building department. Any html webpages are time-stamped with the date when the snapshot was taken, and so could be used to determine whether the city had a link available for a residential PV checklist in any given year. Archived PDFs needed to be viewed more cautiously, as they did not contain timestamps – to some extent, this precluded determining whether cities met more strenuous criteria (for example, only requiring approval from one building department) even if it could be confirmed that they had a PV checklist online in a given year.

3.2.2. Permitting fees

3.2.2.1. Original data collection for permitting fees indicator. An initial base of permitting fee data was built from two existing datasets, then supplemented with information sourced from web archives and news reports. The first of these two sets was a substantial database of California city solar permitting fees from a project led by Kurt Newick in which the Sierra Club gathered permitting fee information for many California cities between 2005 and 2012 (Kurt Newick pers. comm; Mills and Newick, 2008; Mills, Newick, Stewart, and Compeán, 2009). The second data set used was Project Permit, which provided a snapshot of whether cities "passed" or "failed" the test for reasonable permitting fees in 2013. Project Permit used a cut-off of $400 to either pass or fail cities on the criterion of "fair permitting costs."

Coding for permitting fees was restricted to whether cities had fees under or over $400 in any given year, with cities charging fees under $400 being coded as "1" and cities with fees over $400 being coded as "0." The cut-off of $400 is based on recommendations by IREC (IREC, 2013). If a city charged fees under $400 when surveyed by the Sierra Club, then still charged fees under $400 when surveyed by Project Permit, it was assumed that the city also charged reasonable permitting fees during the intervening time; this is considered a reasonable assumption because there was little publicity of permitting fees prior to Newick's work (Mills and Newick, 2008). If there was evidence that the city had instituted a potentially temporary fee waiver that may have expired in the interim (i.e., any case where city fees were observed to be $0 during some years), then the city was coded as missing information on permitting fees.

Newick notes that cities typically either charge solar fees based on the time it takes staff to process permits (leading to reasonable permitting fees), or based on a percentage of the value of the installed solar system (leading to much higher permitting fees). It was thus assumed that, if a city was observed to drop its fees by several hundred dollars to fall below the $400 threshold, the city was highly likely to have switched from a "valuation" method to a "processing time" method of calculating permitting fees. Thus, cities with a substantial observed drop in fees were assumed to have charged higher fees consistently before this drop and were coded accordingly.

3.3. Potential model issues

Endogeneity issues in the form of omitted variable bias and reverse causality could not be ruled out, and a suitable instrumental variable could not be identified to address these issues technologically; for example, any variable that would influence local government decisions to use resources to implement a solar policy (as opposed to using resources to meet another city need) could also influence decisions to install solar directly. In absence of a technological treatment, the following sections provide a detailed discussion of the expected form and direction of impact these endogeneity issues will have on results interpretations.

3.3.1. Omitted variable bias

Use of fixed effects modelling controls for time-invariant unobservables, but there may exist time-varying unobservables that are correlated with both PV installation rates and the decision to adopt streamlined permitting. This would create an omitted variable violation, causing estimates to be biased. The main concern in this model is unobserved variables that may impact both local government decisions to streamline permitting and simultaneously affect resident decisions to install solar PV. One such unobservable may be solar company marketing activities, which could vary across cities and time such that cities with unobserved higher solar marketing may have correspondingly higher PV installation rates. Several solar companies were contacted regarding records of their marketing activities, and it was found that at least one of the major companies simply did not retain geographical marketing data for more than the most recent year. Given that much marketing activity would be door-to-door or online, rather than tied to print ads that could be traced geographically, the necessary marketing data could not be gained for the full timeline of the study 2005–2013.

Previous research has found that marketing can act as a "spark event" for encouraging solar installation (Rai et al., 2016). The link between solar marketing activities and city decisions to streamline permitting is less established, but streamlined permitting procedures are expected to reduce costs for solar installers (Miller, 2014). Case studies of Sacramento, San Francisco, and Lancaster PV permitting reform all discuss influences of the solar industry (ICMA, 2015; NREL, 2011; SF Environment, 2012). In all three cases, discussions or roundtables with local stakeholders influenced plans to streamline solar permitting procedures to reduce time and complexity for the permit process. Thus, a decision by a solar installer to increase activity in any given city may be correlated with both PV installations and with city government interest in streamlining permitting. Both of these correlations are expected to be in the positive direction, which would inflate coefficient estimates, and positive results would thus need to be viewed cautiously.

3.3.2. Reverse causality

There is an additional risk of reverse causality, particularly given that case studies of San Diego and Santa Clara report streamlining permitting procedures after facing difficulties processing increasing numbers of PV permit applications under their prior systems (City of San Diego and the California Center for Sustainable Energy, 2009; SunShot and North Carolina Solar Center, 2013). Solar permitting in San Diego used to be over the counter, but when the city began receiving 40 permit requests each month it no longer had sufficient staff to process them over the counter and permit times slowed, which likely contributed to fully streamlined permitting being rolled out in 2012 (City of San Diego and the California Center for Sustainable Energy, 2009). It is conceivable that other cities may also have chosen to implement streamlined permitting if there was, or was expected to be, a large increase in PV installations, to prevent their planning staff from being overwhelmed; thus, it may be that increasing PV installations prompt streamlined permitting rather than vice versa.

If permitting is streamlined in expectation of higher PV installation rates in future, a positive coefficient would still be expected for the streamlined permitting variable – that is, it would still be expected that the rate of PV installation would increase following implementation of streamlined permitting. This requires caution interpreting positive result coefficients. Likewise, if an increase in PV installations prompts implementation of streamlined permitting, then the years following the streamlining of permitting would be expected to have an even higher rate of PV installations if the rate were in turn influenced by permitting processes. However, if streamlining permitting does not have an effect on PV installation rates, then the rate would instead be expected to continue at the high level that prompted permitting to be initially streamlined. In the latter case, the null hypothesis that streamlining permitting has no effect on PV installation rates cannot be ruled out.

3.4. Dependent variable: Rate of PV system installation

Two dependent variables were examined: (1) watts (W) per capita of PV installed each year, and (2) the number of PV systems per 1000 people installed each year. PV systems between 1 and 10 kW were included in sums of city PV capacity. Though net metering incentives are extended to systems up to 1 MW in size, guidelines for expedited solar permitting are generally created only for smaller systems under 10 or 15 kW (CPUC, 2016; Kaatz and Anders, 2015). Previous studies examining residential solar have also limited analysis to systems 10 kW and under, in absence of records indicating whether a given installation is residential or commercial (Kwan, 2012). As residential systems are an average size of around 5 kW, a cutoff of 10 kW is considered sufficiently representative.

Berkeley Lab's "Tracking the Sun" dataset was used to source zip

code level information on annual installation of solar PV systems (Lawrence Berkeley National Lab, 2016a). Data for California in 2014 and 2015 is not provided by this data set, due to concerns about accuracy as record keeping transitioned between California agencies with the expiry of SB 1. A supplementary analysis was additionally performed using quarterly California Solar Initiative (CSI) data between 2007 and 2013. Although CSI data is included in the Tracking the Sun data set, running a supplementary analysis limiting data to that gathered by one program limits the potential for apparent results to be due to discrepancies in data collection between different agencies or different incentive programs. No differences were found regarding which variables had statistical significance between using CSI and Tracking the Sun data sets.

3.5. City characteristics

The following city characteristics were included in the model as control variables, given that prior literature had established their importance as predictors of residential PV installation. City membership in ICLEI and presence in each city's General Plans of a section specifically targeting environment or sustainability were also investigated for use as control variables, but given that these did not have statistical significance and additionally had limited literature support, these variables were not included in the final regression.

3.5.1. PACE

PACE financing was coded 1 for each year during or after a city passed a resolution to adopt its first PACE program. Specific programs included in searches included the HERO program, CaliforniaFIRST, AllianceNRG, and FigTree. PACE programs such as BerkeleyFIRST that are city or region specific were also included. PACE measurement is complicated by the fact that in July 2010, the Federal Housing Finance Agency (FHFA) issued supervisory guidance that PACE could introduce soundness concerns for mortgages, and this had the effect of stalling or temporarily suspending some PACE programs. However, many jurisdictions that had implemented PACE in early years restarted their PACE programs shortly after this disruption, and many other cities continued to join PACE programs in later years despite the lack of resolution of the FHFA guidelines (Kaatz and Anders, 2014). Thus, the most consistent treatment of PACE was determined to be assuming that programs continued uninterrupted from their start month. A subsample was run excluding all cities that began their PACE programs before 2011 (reducing the sample from 23 to 17 cities); the results of this analysis yielded variable sizes and significances comparable to the main analysis.

3.5.2. Income

Greater income is expected to be associated with higher installation rates of residential PV. The share of households with income over $100,000 and between $50,000-$99,000 is taken from ACS 1-year estimates, both for consistency throughout all time periods and to make use of most current data in each year.

3.5.3. Education

Cities with more educated populations are expected to have higher installation rates of residential PV. The share of the population in each city over age 25 with a Bachelor's degree or higher was taken from the ACS 1-year estimates.

3.5.4. Age

Cities with residents of a greater median age are expected to have higher rates of residential solar installation. ACS 1-year estimates were used to determine the median age in each city for each year. A square transformation was applied to this variable as increasingly higher median age was expected to have an increasing positive impact on increases in PV installation rates.

3.5.5. Voting preferences

Cities with a higher share of democrats are expected to have higher installation rates of residential solar. County-level registered voter preferences were assigned to each city, recording the percent registered as democrats as recorded in the Secretary of State voter registration statistics (California Secretary of State, 2015).

3.6. Utility characteristics

ArcGIS was used to match the 2015 California Energy Commission (CEC) maps of California utility service areas with the 2015 boundaries of cities from the US Census Bureau (CEC, 2015). Utilities were spatially joined wherever they intersected with cities, to identify which utilities served each city and also if multiple utilities served some cities. Cases where overlap occurred were then examined individually, and if over 90% of the city's area overlapped with a single utility then that utility was assigned to the entire city. Two cities did not meet this criterion (Modesto and Mission Viejo, where the majority utility covered less than 80% of city's area), and were dropped from the sample.

3.6.1. Financial incentives

The California Solar Initiative (CSI) was established in 2006 by SB 1, and all cities within Investor Owned Utility (IOU) territories have been eligible for rebates through the CSI since 2007, and prior to that were eligible for rebates through the Emerging Renewables program. Cities served by Publicly Owned Utilities (POUs) were required by SB 1 to have access to rebates from January 2008 onwards, and POUs serving cities in the sample had all implemented rebate programs prior to 2008 except for Alameda Power & Telecom. Due to California's stringent support of residential solar PV, nearly all cities had access to rebates through state-mandated programs for all years 2005–2013.

Although nearly all utilities offered financial incentives for residential solar PV over the years studied, the California legislation both allowed for variations between utilities and required that the financial incentives offered decline over time. Following the introduction of SB 1, all utilities used incentive schedules that declined through set tiers as thresholds for participation were met. That is, the rebate rate would decline after a given quantity of kW had been installed in the utility's territory.

These rate schedules, and the rate for each utility in any given year, were gathered from archived utility and DSIRE webpages. With the exception of LADWP, all utilities recorded rates in terms of $/kW installed solar; thus the rates in $/kW were used for modelling input (no LADWP cities were included in the final sample). A logarithmic transformation was applied to this variable as increasingly higher incentives are expected to have a decreasing impact on increases in PV installation rates.

3.6.2. Electricity prices

US Energy Information Administration (EIA) form 861 was used to determine average bundled residential prices for each utility. Each city was assigned the average price in that year for the utility it is served by. A logarithmic transformation was applied to this variable, as increasingly higher prices are expected to have a decreasing impact on increases in PV installation rates.

3.6.3. Third Party Ownership

Analysis controlled for availability of Third Party Ownership (TPO) by excluding utilities from analysis if they had ever prohibited leasing. IOUs allowed connections by TPO systems from 2008 onwards, but some POUs did not allow TPO for several more years. Access to TPO was coded 0 for all cities prior to the year 2008, and 1 for all cities for the year 2008 and onwards. This was then refined by stated POU policies on utility websites, as found from web archives and press releases announcing changes to leasing availability. When coding was completed, it was notable that only one municipal utility (Roseville)

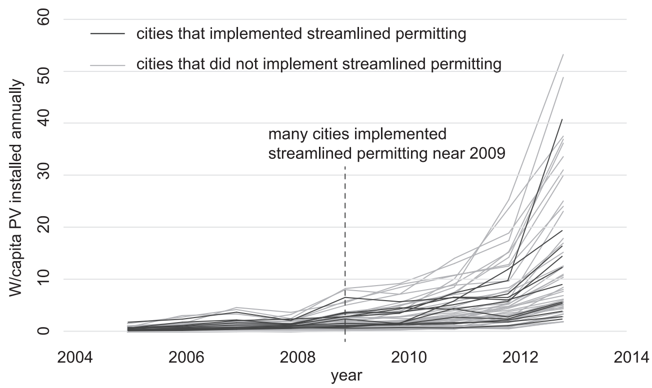

Fig. 2. PV installation trends in cities that did versus did not implement streamlined permitting.

disallowed TPO for multiple years after it was widely available to IOU customers, and Roseville was removed from the sample.

4. Analysis

After constructing the dataset identifying when each city had streamlined permitting, it was possible to visually compare PV installation trends across cities based on their permitting status. This simple visual comparison is presented in Fig. 2. A large amount of variation cannot be attributed to cities implementing streamlined permitting procedures. Many cities implemented streamlined permitting near the year 2009 (see Table 2), so relatively similar trends revealed by visual inspection of Fig. 2 prior to this year indicate that fixed effects analysis may offer further insight as to the impact of streamlined permitting on PV installation rate trends. It is notable Fig. 2 shows cities that implemented streamlined permitting during the study period unexpectedly had lower per-capita installation rates by 2013 than some of the cities that didn't. Four cities (including Berkeley) were excluded from the fixed effects analysis (and from Fig. 2) as visual inspection indicated that they had unusual trends not in line with those of other cities pre-2009.

Fixed effects analysis is used to further investigate the impact of streamlining permitting, while controlling for differences between cities. The results of this analysis cannot rule out the null hypothesis that streamlining permitting has no effect on solar installation rates. Figs. 3 and 4 plot the coefficients from this fixed effects analysis with error bars at the 95% confidence level, and it is notable that in both cases the estimates are not precise enough to determine whether the effect is

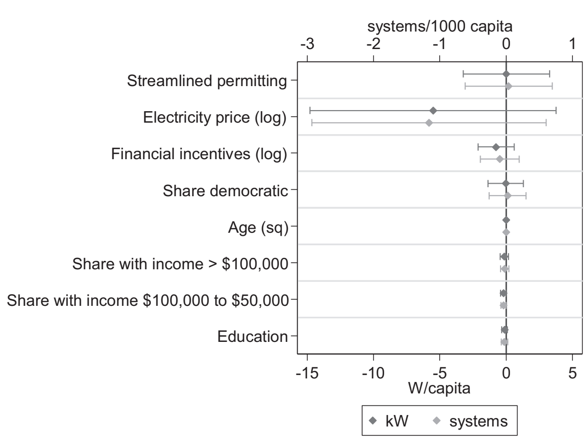

Fig. 3. Main sample (N = 53 cities): Coefficients from fixed effects model of factor impacts on PV installation rates, using cluster robust standard errors clustered at city level. All models included fixed effects dummies for year and city, with 95% confidence intervals. Table provided in Appendix.

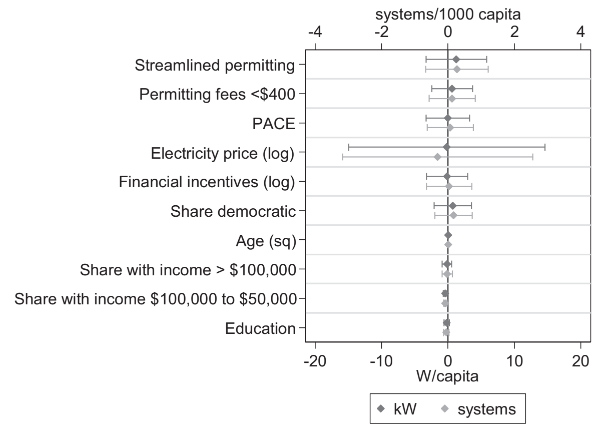

Fig. 4. Sub-sample (N = 23 cities): Coefficients from fixed effects model of factor impacts on PV installation rates, using cluster robust standard errors clustered at city level. All models included fixed effects dummies for year and city, with 95% confidence intervals. Table provided in Appendix.

positive or negative. Table A1 in the Appendix details coefficient sizes for the fixed effects model. The coefficient for streamlined permitting remains statistically insignificant for both dependent variables (W/capita installed annually and number of PV systems/capita installed annually), for both main sample and the sub-sample (including PACE and permitting fees). Additional tests were run to examine whether the model was sensitive to specifying the dependent variable using number of owner-occupied houses or number of single-unit owner occupied houses in each city rather than city population, and two additional models were run examining quarterly (rather than annual) installations from 2007 to 2013 using both CSI and Tracking the Sun datasets. The model was also examined excluding POUs from the analysis, since there is a possibility that data collection methods for these utilities differed from those of IOUs (IOUs are expected to be more consistent). These model variants all failed to reject the null hypothesis that streamlining permitting has no impact on residential solar installation rates.

Of the control variables, only one was significant. Having a higher share of households with income of $100,000 to $50,000 predicted lower rates of PV installations for only the sub-sample analysis including permitting fee and PACE impacts. Neighborhoods with higher shares of incomes above $100,000 were not associated with higher rates of PV installation, despite expectations that this would be an important predictor based on findings at the individual level that financial factors are an important predictor of PV installations.

5. Policy implications

As national and state level leadership are slow or reluctant to introduce policies that mitigate climate change, local governments have been looked-to as actors able to more immediately influence emissions reduction (Bulkeley, 2010; Fiorino, 2014). It was hypothesized that local government actions to remove barriers to residential solar PV by streamlining permitting procedures would lead to increased PV installation rates, by reducing cost and time needed to install these systems. However, analyses in the current paper are unable to reject the null hypothesis that streamlining permitting has no effect on PV installation rates. Given the emphasis on local policies as an avenue to implement policies mitigating climate change, it is a cause for concern that even in California, which has comparatively aggressive data gathering in this area, there is insufficient information to more definitively determine the impact of streamlined permitting procedures on residential PV installation rates.

The results of analyses in this paper indicate that it must be considered that streamlining permitting may in fact not have any impact on residential PV rates. Modelling ruled out the possibility of very large

effects of city level policies in California on PV installation rates; if city streamlining of permitting policies was a powerful driver of residential PV installation rates, then an effect was expected to be seen despite the small sample size gathered, and potential modelling issues identified were expected to inflate any observed effect rather than mask it. The inability to reject the null hypothesis nonetheless advances literature in this area; prior research has not been published attempting to determine whether streamlining permitting causes an increase in residential PV installation rates. By making the present result widely available to the research community it is expected that future research can strengthen the areas where the current modelling approach fell short due to data limitations, for example by developing a focus on real-time data scraping of local policy information over several years. Evaluation of city-level policies to determine quantitative impacts will be key in future years if cities continue to be emphasized as an area for action on climate change, because findings from quantitative evaluations can allow cities to focus their limited resources more directly on the most effective policies.

6. Limitations and future research

The study was restricted to a relatively small sample of 53 cities over 9 years, only 11 of which implemented streamlined permitting during the period 2005–2013. This limited the ability of fixed effects analysis to identify significant policy effects. Further, it is possible that the model contained endogeneity, though this was expected to inflate coefficients rather than suppress them thus does not explain the null result (discussed in Section 3.3). Analysis was also limited to the state of California, as sufficient records of city-level PV installations do not exist in most other states over a sufficient time horizon, and streamlined permitting processes are so sparse outside California that the sample size would have been drastically smaller than even the limited sample in the current paper. Cities in different geographical settings will face different regulatory and financial constraints by regional and national actors, so findings from California are not expected to be generalizable across all localities.

Several additional factors were considered for inclusion in the fixed effects analysis, but no sources of historical data could be identified so these factors could not be modelled. In particular, no measures were available regarding the length of time and cost of inspections of PV systems following initial issuance of the permit, though these inspections are also expected to present a barrier to PV installation (IREC, 2013). Further, the permitting was not assessed based on the number of departments involved in review of the systems, which may also introduce additional barriers, since this data is often not widely available even for the present year. Additionally, lack of detailed time-series data precluded TPO from inclusion in any analyses, despite the expectation that availability of different ownership options may be an important predictor of residential PV uptake (Corfee et al., 2014).

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Appendix

see Table A1

Table A1
Fixed effects model of factor impacts on PV installation rates, using cluster robust standard errors clustered at city level. All models included fixed effects dummies for year and city.

	W/capita PV installed annually (main sample)	Number of PV systems installed/1000 people annually (main sample)	W/capita PV installed annually (sub-sample)	Number of PV systems installed/1000 people annually (sub-sample)
Streamlined permitting	0.03	0.04	1.26	0.27
	(1.62)	(0.33)	(2.21)	(0.45)
Permitting fees < \$400			0.63	0.13
			(1.47)	(0.33)
PACE			− 0.03	0.07
			(1.58)	(0.34)
Electricity price (log)	− 5.51	− 1.16	− 0.18	− 0.31
	(4.63)	(0.88)	(7.13)	(1.38)
Financial incentives (log)	− 0.75	− 0.09	− 0.14	0.03
	(0.68)	(0.15)	(1.49)	(0.33)
Share democratic	− 0.03	0.02	0.72	0.17
	(0.66)	(0.14)	(1.35)	(0.27)
Age (sq)	0.01*	0.00**	0.01*	0.00*
	(0.00)	(0.00)	(0.00)	(0.00)
Share with income > \$100,000	− 0.13	− 0.02	− 0.16	− 0.02
	(0.15)	(0.03)	(0.34)	(0.07)
Share with income \$100,000 to \$50,000	− 0.20^{+}	− 0.04^{+}	− 0.41**	− 0.08**
	(0.11)	(0.02)	(0.14)	(0.03)
Education	− 0.11	− 0.02	− 0.21	− 0.05
	(0.11)	(0.02)	(0.19)	(0.04)
R^2	0.53	0.53	0.53	0.53
N	476	476	207	207

Standard errors in parentheses.

*** $p < 0.001$.

$^{+}$ $p < 0.10$.

* $p < 0.05$.

** $p < 0.01$.

References

Betsill, M., Rabe, B., 2009. Climate change and multi-level governance: the evolving state and local roles. In: Mazmanian, D.A., Kraft, M.E. (Eds.), Towards Sustainable Communities.

Bulkeley, H., 2010. Cities and the governing of climate change. Annu. Rev. Environ. Resour. 35 (1), 229–253. https://doi.org/10.1146/annurev-environ-072809-101747.

Bulkeley, H., Betsill, M.M., 2013. Revisiting the urban politics of climate change. Environ. Polit. 22 (1), 136–154. https://doi.org/10.1080/09644016.2013.755797.

Burkhardt, J., Wiser, R., Darghouth, N., Dong, C.G., Huneycutt, J., 2015. Exploring the impact of permitting and local regulatory processes on residential solar prices in the United States. Energy Policy 78, 102–112. https://doi.org/10.1016/j.enpol.2014.12.020.

California Secretary of State, 2015. Voter Registration Statistics. Retrieved July 10, 2016, from 〈http://www.sos.ca.gov/elections/voter-registration/voter-registration-statistics〉.

CEC, 2015. California Electric Utility Service Areas Map. Retrieved January 16, 2016, from 〈http://www.energy.ca.gov/maps/serviceareas/Electric_Utility_Service_Areas.html〉.

City of San Diego and the California Center for Sustainable Energy, S, 2009. Barriers and Solutions: A Detailed Analysis of Solar Photovoltaics in San Diego.

Corfee, K., Cullen, J., Graham, S., Fry, N.R., Davis, B., Meyer, A., Bloch, C., 2014. California Solar Initiative: Third-Party Ownership Market Impact Study. San Francisco.

CPUC, 2016. Net Energy Metering (NEM). Retrieved March 16, 2016, from 〈http://cpuc.ca.gov/General.aspx?Id=3800〉.

Davidson, C., Drury, E., Lopez, A., Elmore, R., Margolis, R., 2014. Modeling photovoltaic diffusion: an analysis of geospatial datasets. Environ. Res. Lett. 9 (7), 074009. https://doi.org/10.1088/1748-9326/9/7/074009.

Dong, C., Wiser, R., 2013. The impact of city-level permitting processes on residential photovoltaic installation prices and development times: an empirical analysis of solar systems in California cities. Energy Policy 63, 531–542. https://doi.org/10.1016/j.enpol.2013.08.054.

Feiock, R.C., Krause, R.M., Hawkins, C.V., Curley, C., 2013. The integrated city sustainability database. Urban Aff. Rev. 50 (4), 577–589. https://doi.org/10.1177/1078087413515176.

Fiorino, D.J., 2014. Sustainable cities and governance: what are the connections? In: Mazmanian, D.A., Blanco, H. (Eds.), Elgar Companion to Sustainable Cities: Strategies, Methods and Outlook. Edward Elgar Publishing Limited, pp. 413–433.

Hsu, J.H.-Y., 2018. Predictors for adoption of local solar approval processes and impact on residential solar installations in California cities. Energy Policy 117, 463–472. https://doi.org/10.1016/j.enpol.2018.03.008.

ICMA, 2015. Solar Case Study: Lancaster, California. Retrieved from 〈https://www.google.com/url?Sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwiUl-GOicPPAhWI7IMKHTDCA3cQFggeMAA&url=http%3A%2F%2Ficma.org%2FDocuments%2FDocument%2FDocument%2F307197&usg=AFQjCNEa3UjjSYInYc0t8rN8kUSCfD5yVw&sig2=tl-tKlklvvdHXUiNPv〉.

IREC, 2013. Simplifying the Solar Permitting Process: Residential Solar Permitting Best Practices Explained. Retrieved from 〈http://www.irecusa.org/publications/residential-solar-permitting-best-practices-explained/〉.

Kaatz, J., Anders, S., 2015. AB 2188: Implementation of the Solar Rights Act at the Local Level (Rev. ed.). Retrieved from 〈http://energycenter.org/sites/default/files/docs/nav/policy/research-and-reports/AB_2188_Implementation_Guide.pdf〉.

Kaatz, J., Anders, S.J., 2014. Residential and commercial property assessed clean energy (PACE) financing in California rooftop solar challenge areas. Retrieved from 〈http://energycenter.org/sites/default/files/docs/nav/policy/research-and-reports/PACE_in_California.pdf〉.

Kirkpatrick, A.J., Bennear, L.S., 2014. Promoting clean energy investment: an empirical analysis of property assessed clean energy. J. Environ. Econ. Manag. 68 (2), 357–375. https://doi.org/10.1016/j.jeem.2014.05.001.

Kwan, C.L., 2012. Influence of local environmental, social, economic and political variables on the spatial distribution of residential solar PV arrays across the United States. Energy Policy 47, 332–344. https://doi.org/10.1016/j.enpol.2012.04.074.

Lawrence Berkeley National Lab, 2016a. Tracking the Sun Public Data File. Retrieved August 24, 2016, from 〈https://openpv.nrel.gov/assets/data/openpv_tts_data.zip〉.

Lawrence Berkeley National Lab, 2016b. User Guide for Tracking the Sun Public Data File.

Li, H., Yi, H., 2014. Multilevel governance and deployment of solar PV panels in U.S. cities. Energy Policy 69, 19–27. https://doi.org/10.1016/j.enpol.2014.03.006.

Miller, M.J., 2014. Did Pookie Get A Green-collar Job?: a Critical Case Study on the East Bay Green Corridor's Employment Goals, Activities, and Impacts. Massachusetts Institute of Technology. Retrieved from 〈https://dspace.mit.edu/handle/1721.1/90213〉.

Mills, C., Newick, K., 2008. Solar Electric Permit Fees in Northern California: a Comparative Study.

Mills, C., Newick, K., Stewart, J., Compeán, T.W., 2009. Solar Electric Permit Fees in Southern California: A Comparative Report.

Newick, K., Personal communication.

NREL, 2011. Sacramento, California: Solar in Action, Solar America Cities, Energy Efficiency and Renewable Energy. Retrieved from 〈https://energy.gov/sites/prod/files/2014/01/f7/51057_sacramento.pdf〉.

Pitt, D., 2008. Taking the Red Tape out of Green Power.

Rai, V., Reeves, D.C., Margolis, R., 2016. Overcoming barriers and uncertainties in the adoption of residential solar PV. Renew. Energy 89, 498–505. https://doi.org/10.1016/j.renene.2015.11.080.

Robinson, S.A., Rai, V., 2015. Determinants of spatio-temporal patterns of energy technology adoption: an agent-based modeling approach. Appl. Energy 151, 273–284. https://doi.org/10.1016/j.apenergy.2015.04.071.

Seel, J., Barbose, G.L., Wiser, R.H., 2014. An analysis of residential PV system price differences between the United States and Germany. Energy Policy 69, 216–226. https://doi.org/10.1016/j.enpol.2014.02.022.

Seto, C.K., Dhakal, S., Bigio, A., Blanco, H., Delgado, G.C., Dewar, D., Ramaswami, A., 2014. Human Settlements, Infrastructure and Spatial Planning (In) In: Z., T., Edenhofer, J.C.M., O., Pichs-Madruga, R., Sokona, Y., Farahani, E., Kadner, S., Seyboth, K., Adler, A., Baum, I., Brunner, S., Eickemeier, P., Kriemann, B., Savolainen, J., Schlömer, S., von Stechow, C. (Eds.), Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

SF Environment, 2012. San Francisco's Streamlined Solar Permitting. Retrieved from 〈http://sfenvironment.org/sites/default/files/fliers/files/san_franciscos_streamlined_solar_permitting.pdf〉.

SunShot and North Carolina Solar Center, 2013. Harmonizing Solar PV Permitting and Interconnection in Santa Clara, CA. Retrieved from 〈https://nccleantech.ncsu.edu/solar-center-releases-new-case-study-harmonizing-solar-pv-permitting-and-interconnection/〉.

Treadwell, T., Gishri, T., Wheeland, J., Anders, S., Kaatz, J., 2012. Streamlining Solar Standards and Processes Southern California Rooftop Solar Challenge.